U.S. Department of Agriculture Agricultural Research Service November 1993

Agricultural Research

Pear Pest Research Bears Fruit

For a Stronger Fruit Industry

When dedicated in 1979, the Appalachian Fruit Research Station (AFRS) at Kearneysville, West Virginia, was commissioned to serve the needs of the eastern U.S. fruit production area from Maine to Georgia. ARS scientists here work to support, strengthen, and expand the East Coast fruit industry to give consumers a wider choice of apples, peaches, pears, nectarines, apricots, plums, strawberries, and thornless blackberries.

The intervening years have broadened the scope of the station's work and brought collaborative research with national and international organizations.

In line with the challenge of the 1990's to promote food safety and protect the environment, scientists at Kearneysville have established cooperative research and development agreements with EcoScience in Amherst, Massachusetts, and Ecogen, based in Langhorne, Pennsylvania—companies that are developing alternatives to pesticides.

These companies hold licenses to market naturally occurring organisms discovered and patented by AFRS scientists that protect fruits and vegetables from postharvest diseases.

The research station's clients range from small farmers who sell strawberries and apples at roadside markets and look for help in increasing their production, to large growers who may need results from our research on molecular biology and genetic engineering.

Some AFRS projects that should soon benefit fruit growers include:

- Development of recirculating orchard spray equipment for use on apples that will significantly reduce the volume of chemical pesticides applied in orchards. This technology and equipment can be adapted for use on many tree fruit crops, resulting in better quality fruit and a much cleaner, safer environment.
- Identification of several genes that are involved in softening of peaches as they ripen. These genes are candidates for producing genetically engineered peaches that can be marketed at a riper, sweeter stage without quickly deteriorating on the grocer's shelves.
- Collaboration with other research institutions on a peach genome map that would greatly reduce the time necessary to breed new, improved peach varieties.
- Introduction of management practices for young orchards that reduce soil erosion and protect underground water supplies. Establishing and maintaining a productive orchard now depends on synthetic fertilizers and pesticides. By planting grass groundcovers such as fescue beneath trees and between rows and then killing the grass and leaving it on the ground to protect the soil, we have increased fruit yield by 50 percent. And the grass has diminished rainfall runoff, thereby reducing soil erosion. This "killed sod" treatment has also helped control soil nematodes and has increased soil organic matter at less cost than applying compost.
- Design and patenting of a new valve for controlling irrigation water that senses when and how much water to release into the soil for orchard and row crops such as strawberries and vegetables. The valve has only one moving part and does not require electricity.
- An interdisciplinary effort involving a horticulturist and a plant pathologist at Kearneysville, working with a researcher at the University of Maine. The AFRS scientists have selected and identified 12 yeast and bacterial antagonists from populations of naturally occurring microorganisms on ripe strawberries that help prevent gray mold *(Botrytis)* on strawberries. Currently controlled with fungicides, *Botrytis* is the major disease that attacks strawberries and other small fruits. One of the antagonists is now undergoing field tests in Maine. Although not as effective as fungicides, the antagonists have given good control of the disease under postharvest conditions and would be even more effective if used along with other controls.

In our efforts to find alternatives to chemicals to protect and preserve the food supply, we are relying on a combination of natural weapons, along with pesticides. This combination approach will reduce the amount of chemicals released into the environment. And as the cover story in this issue shows, we are also using biotechnology to breed insect and disease resistance into pears and other fruits.

The changing face of American agriculture presents many challenges to agricultural research. Here at Kearneysville, we anticipate the demands these challenges place on our research efforts and work hard to improve quality and production efficiency that not only affect U.S. consumers, but will also increase our competitive edge in world markets.

Stephen S. Miller
Director, ARS Appalachian Fruit Research Station

Agricultural Research

Cover: **Though the pears pictured do not have a texture suitable for good eating, scientists at the ARS Appalachian Fruit Research Station in Kearneysville, West Virginia, will combine their fire blight-resistant qualities with other lines possessing traits sought in commercial pear varieties.** Photo by Keith Weller. (K5299-1)

Page 12

Page 17

Page 23

Vol. 41, No. 11
November 1993

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Agricultural Research is published monthly by the Agricultural Research Service, U.S. Department of Agriculture, Washington, DC 20250-2350.

The Secretary of Agriculture has determined that publication of this periodical is necessary in the transaction of public business required by law.

Subscription requests should be placed with New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954. Please see back cover for order form.

This publication was printed with soybean oil-based ink.

When writing to request address changes or deletions, please include a recent address label.

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Scientists Seek Limits On Pear Pests

Success could spell expansion of U.S. commercial production areas.

Homer called pears one of the "gifts of the gods," and more than 2,000 years ago, the Greek naturalist Theophrastus wrote about the differences between wild and cultivated pears.

Even in ancient times, pruning roots and girdling stems were said to hasten fruiting. But then, driving iron pegs into the trunk to "punish" the tree was also said to make the tree bear fruit earlier.

Pears are known to have been under cultivation in New England as early as 1629. The first record of a nursery selling pear trees is from Massachusetts in 1641.

"Until about the middle of the 18th century, Massachusetts was the center of the American pear industry," says Howard J. Brooks, ARS associate deputy administrator for plant sciences. "And up until the 19th century, most of the new pear varieties and nearly all of the introductions from abroad came by way of Massachusetts."

Those introductions, he says, are probably the offspring of pear seeds imported by French, Dutch, and English settlers in America.

Legend has it that the pear trees that were early landmarks along the Detroit River in Michigan were descendants of three pear seeds brought to America in the vest pocket of a French emigrant.

The establishment in 1730 of a nursery in Flushing, Long Island, New York, gave the fledgling East Coast pear industry a boost. That nursery was unique: It sold budded or grafted pear trees. Until then, pears—as well as most other fruits—were grown from seeds.

"Coincidental with this event came another of paramount importance to pear growers," Brooks says. "Fire blight appeared on the scene and became epidemic in orchards along the Hudson River in the 1790's."

Pears are known to have been under cultivation in New England as early as 1629.

For the East Coast pear industry, this was the beginning of the end, for fire blight eventually wiped out most of the eastern U.S. pear orchards.

And the demise was further aided by pear psylla, a small, aphid-sized insect first discovered in the United States in Connecticut in 1832.

Now, ARS plant pathologists, horticulturists, and entomologists at the Appalachian Fruit Research Station in Kearneysville, West Virginia, are helping to revive this long-lost East Coast fruit industry. Their research could also help ensure the continuing health of the existing industry on the West Coast.

These scientists have new ways to fight the deadly blight, caused by the bacterium *Erwinia amylovora*. And they also have innovative ways to combat the pernicious insect.

In addition to breeding new pear varieties that are resistant to fire blight and using a computer program to predict blight from weather conditions, they are investigating environmentally safe, biological methods to control the pear psylla. And breeding a tree that isn't bothered by the insect offers yet another possible solution.

Fire Blight—Can We Prevent It?

"Fire blight is indigenous to North America," explains Tom van der Zwet, a plant pathologist at Kearneysville. "It was well over a century after that first discovery, in the Hudson Valley, that this disease was reported in a foreign country."

KEITH WELLER

Front row, center: Shining among nine other advanced pear selections now getting their mettle tested at several U.S. locations, Potomac was released in May 1993. (K5302-1)

Now widespread throughout Western Europe and the eastern Mediterranean region, its effects can be devastating. According to van der Zwet, 95 percent of Egypt's Le Conte pear crop was lost to the disease in 1985.

Fire blight probably first occurred on such American natives as crabapple, hawthorn, and mountain ash, he says. From these hosts, the bacterium could have spread to susceptible cultivated pears and apples planted by early American settlers.

Considered the oldest, most serious, and least understood disease of pomaceous fruit trees, fire blight attacks all parts of a tree—from roots to fruit. Affected areas look scorched and blackened, as though they have been burned. Fire blight is most destructive to pears but also damages apples, quince, and some ornamental plants. Once blight strikes, a tree can die rapidly or within a few years, for treatments such as antibiotic sprays are not wholly effective.

Since the incidence and severity of fire blight are typically very sporadic, accurate estimates of annual losses from fire blight for given localities or for the nation as a whole are difficult to obtain. However, an outbreak of the disease in southwest Michigan in 1991 caused an estimated combined loss of fruit and trees of $3.8 million.

"This disease has its place in history—it was the first plant disease ever attributed to a bacterium," van der Zwet says. "Fire blight was the beginning of plant bacteriology."

In the early 1900's, USDA began the first pear-breeding program under the direction of M.B. Waite and E.F. Smith. In the 1930's, John Magness, chief of the horticulture section of the Plant Industry Station at Beltsville, Maryland, started gathering pear germplasm from around the world.

Magness hybridized the better quality pears that showed resistance to the destructive blight. He made large pear plantings across the river from Washington, D.C., at Arlington Farms, now Arlington National Cemetery. In 1938, the program was transferred to the Agricultural Research Center in Beltsville, where it remained until 1979.

In 1960, USDA hired Brooks to continue the search for a fire-blight-resistant pear. "I spent 7 weeks in southern Russia in 1967 gathering pear germplasm," Brooks recalls, "because the literature reported a vast array of pear genetic material there."

He shared the genetic material he brought back from Russia with U.S. and Canadian scientists also involved with the research.

And to screen and evaluate the new pear seedlings produced from the germplasm, Brooks hired van der Zwet.

Grappling With Fire Blight

Brooks says that fire blight had not been a significant problem in California, Oregon, or Washington until recently. But during the last several years, it has become nearly epidemic in certain West Coast production areas. The new pear varieties that ARS will introduce from the breeding program now located at Kearneysville will also be tested in Western states. If adapted, these varieties could prove better than existing ones, he contends.

"We now ship pears for fresh market from the West to the East Coast," says Brooks. "If the new varieties grow well in the East, they could become an alternative crop there. And consumers would pay less for good-quality, fresh-market pears, since shipping would be eliminated."

KEITH WELLER

Starved: Pears prematurely yellow and shrivel when fire blight cuts off the flow of water and nutrients along tree branches. (K5300-17)

In the 1960's, USDA released two fire-blight-resistant pears—Magness and Moonglow. But only Magness has been grown commercially. Although an extremely high quality pear, Magness is not very productive. Moonglow is still used for backyard production, but its fruit quality doesn't meet commercial standards.

"A new release, Potomac, may be a different story," says Richard L. Bell, Kearneysville horticulturist and pear breeder. "Besides having superior resistance to fire blight, this new pear has excellent flavor and texture. Although we plan to release this variety for home orchards, commercial growers who plan to store the fruit for less than 2 months may also be interested."

Bell says that back in 1961, Brooks made the genetic cross from which Potomac was selected. Potomac has been evaluated in Maryland, West Virginia, Arkansas, New York, Ohio, and Oregon for fruit quality, fire blight resistance, and productivity. Release was approved in May of this year, which means it should be available to growers in about 2 years.

Potomac has light-green, glossy skin and moderately fine and buttery fruit texture with very little grit. The taste is mild, with a good balance of sugar and acid.

"Even more exciting are the newer potential varieties we're working with now," Bell says. "About eight selections from crosses made since the late 1960's—all blight resistant—have been sent to cooperators around the country. All are more blight resistant than Bartlett, the most popular variety."

These varieties are being tested in Ohio, New York, Washington, Oregon, and California. Additional cooperators are being sought in Arkansas, Michigan, and other states. Bell says the varieties have good appearance and size, represent a range in flavor types and harvest dates from early August to early October, and maintain good quality late in storage.

The evaluation process will take some time, Bell says, but several of these new varieties could be released within the next 7 or 8 years.

Computers and Cultural Practices Can Help

"One way growers can fight fire blight is to predict when it will occur, so they can be ready for it," van der Zwet explains. "We've used a computer program developed jointly with the University of Maryland for more than 6 years now, and it has been nearly 100-percent accurate in predicting blight conditions each year."

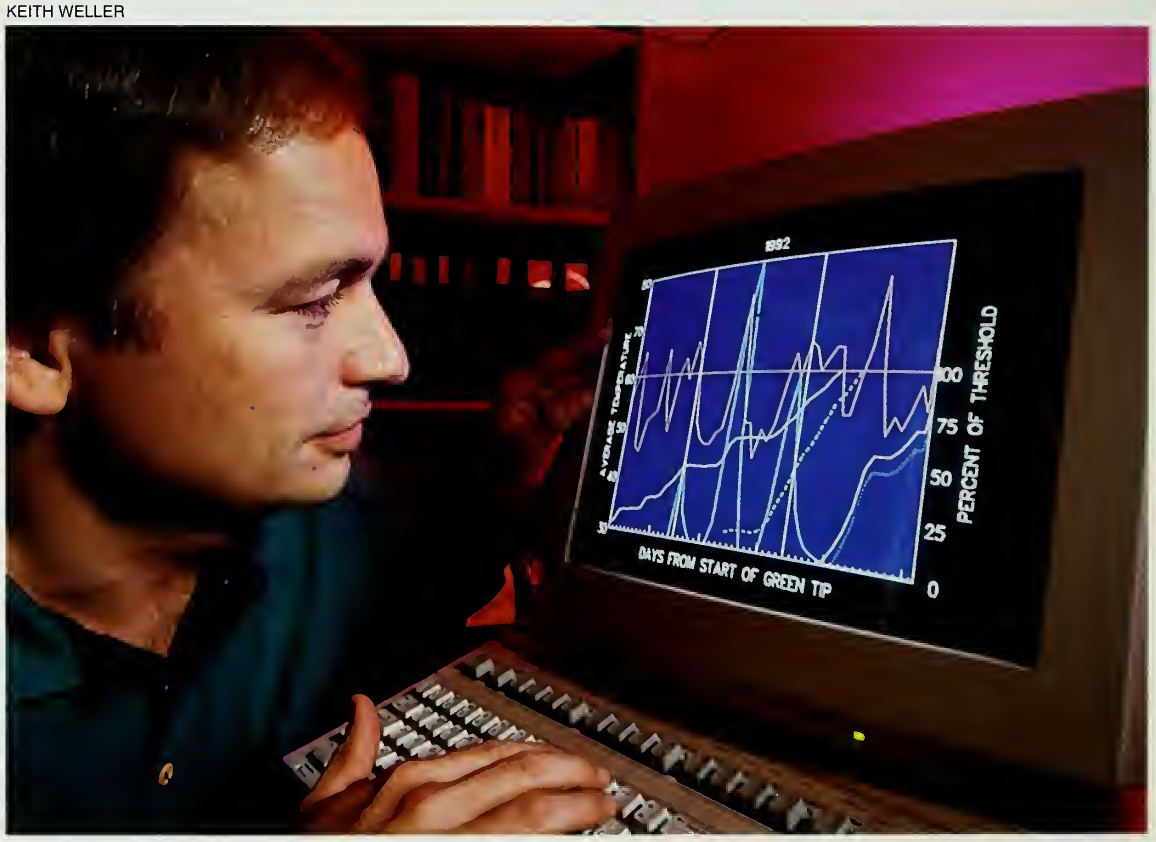
Called MARYBLYT, the program was developed by Paul Steiner, of the University of Maryland, and Gary W. Lightner, an ARS computer analyst at Kearneysville.

"Weather conditions have a lot to do with the bacteria being distributed and infecting trees," van der Zwet says. "Warm, moist conditions are ideal for bacterial growth."

To operate MARYBLYT, a grower needs only a simple rain gauge, a minimum and maximum thermometer, and a sharp eye. The program operates on any IBM or compatible personal computer, including most portables, and is considered easy to run.

Tested at over 20 locations throughout the United States and Canada, the program resulted in better fire blight

KEITH WELLER



Fireblight tracking: Computer specialist Gary Lightner uses MARYBLYT's graph function to chart fire blight infections that occurred at the Kearneysville station in 1992. (K5315-1)

control and reduced the number of antibiotic sprays needed.

"Although some growers spray their pear orchards with streptomycin, it is not absorbed throughout the tree and is not effective on unopened blossoms," van der Zwet says. "Furthermore, some strains of *E. amylovora* are resistant to it. In these instances, copper compounds may be substituted, but these are not nearly as effective."

Since there are stringent rules governing the use of antibiotics on food crops, van der Zwet and colleagues at Kearneysville are also experimenting with what they call "horticultural manipulation" of the tree to prevent the disease from striking.

"Cultural practices such as maintaining an adequate balance of calcium in the soil, making sure proper amounts of fertilizer are applied, and using drip instead of overhead irrigation can reduce the bacterium's spread," van der Zwet notes.

They're also testing biocontrol agents against the disease.

For example, a microorganism found on the leaves of honey locust trees growing in a West Virginia forest may prove to be effective in deterring fire blight. It is a bacterial antagonist that fights *E. amylovora,* and van der Zwet and colleagues have identified a sugar that speeds up its growth. The sugar may help encourage this and other naturally occurring antagonists of fire blight's bacterial carrier to proliferate on the blossoms and leaves of pear and apple.

Additional ARS research on microbial biocontrol of fire blight is conducted at Wenatchee, Washington, and Corvallis, Oregon.

Pear Psylla—Can We Stop It?

A yellowish-green insect that looks like a miniature cicada—the pear psylla—is the other main reason there is no longer a pear industry on the East Coast.

KEITH WELLER

What a problem: Plant pathologist Tom van der Zwet spots severe symptoms from previous year's fire blight infection, while horticulturist Richard Bell is pleased to see normal branches on nearby trees developed from blight-resistant eastern European stock. (K5310-1)

A sucking insect, *Cacopsylla pyricola* is prevalent throughout pear-growing regions of the United States and Canada. When the insects feed on leaves, says Gary J. Puterka, an entomologist at Kearneysville, it causes severe wilting and defoliation, which reduces yields and weakens the trees.

Pear psylla also carry a mycoplasma-like organism (MLO) that causes pear decline, the premature death of pear trees.

And, "If these things weren't bad enough, the immature form of the insect secretes copious quantities of honeydew, a sugary, sticky substance that allows a black, sooty mold to grow on both fruit and leaves," Puterka says. This mold not only reduces the quality of the fruit; it also blocks sunlight from the leaves, decreasing photosynthesis.

Previously, growers controlled pear psylla with insecticides—an expensive and sometimes ineffective method, for the pear psylla has developed resistance to several common ones. Now, growers must rotate the few available pesticides that are appropriate.

So Puterka is taking several different approaches. Natural plant compounds, fungal pathogens, and different orchard ground covers all look like promising controls. And host-plant resistance—another name for identifying pear genetic material with a natural defense against the pest—is another viable alternative.

Sugar Ester and Fungal Pathogens

"The most successful plant compound we've tried so far has been a sugar-ester extracted from wild tobacco," Puterka says.

Mixed with water and sprayed on pear leaves, the sugar-ester gave 100-percent control of the psylla, killing most nymphs within 2 hours. Puterka reports that full control took only a day.

"Even nymphs that hatched 3 to 5 days after spraying were affected," he says. "They appeared normal as they crawled out of the eggs. But when the nymphs walked on a leaf that had been sprayed with the compound, they suddenly died."

The sugar-ester is a nontoxic, natural plant compound that was originally extracted for use against the sweetpotato whitefly by ARS chemist George Buta and entomologist John Neal at Beltsville. Scientists are now searching for a way to mass-produce it. And Ray Severson, an ARS chemist at the Phytochemical Research Laboratory in Athens, Georgia, is collaborating with Puterka on field tests.

Puterka is also testing fungal pathogens, even though none has ever been identified on pear psylla. He got the ones he's using—several naturally occurring strains of *Beauveria, Verticillium,* and *Paecilomyces*—from ARS insect pathologists at Ithaca, New York. Collected from aphids and some psylla species, all gave 100-percent control within 5 days.

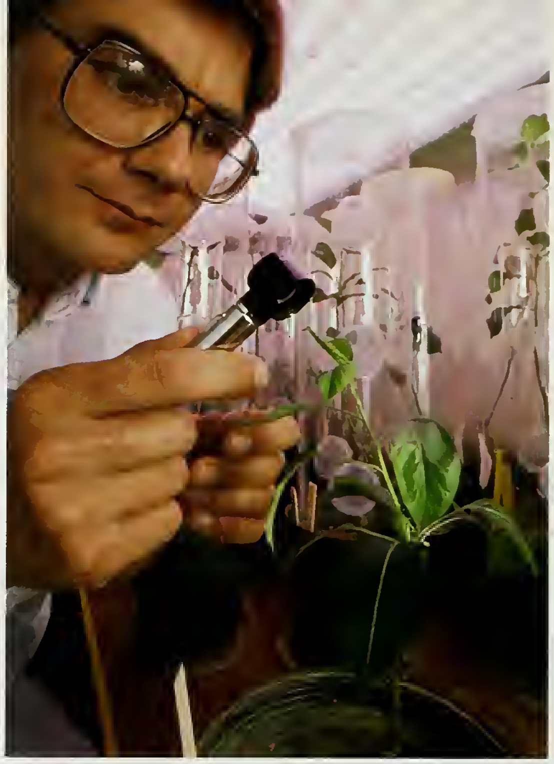
These fungal pathogens have one important advantage over both the sugar-ester control and other insecticides: They have a lasting effect.

"The sugar-ester may linger on the plant for only about a week, whereas the fungus can establish itself in the ecosystem and last indefinitely," Puterka explains.

When applying the pathogenic fungi, Puterka mixes spores with either oil or water and sprays the psylla-infested leaves. Soon after the spray hits the nymphs, they become infected and die in 1 to 3 days. Within 5 days, 100-percent control can be achieved.

Nearly perfect biocontrols, the fungi are host-specific, completing their life cycle on infected insects on the plant—and are therefore nontoxic to humans, animals, or beneficial insects. Dead pear psylla nymphs literally turn into white puffs of fungus. After killing their host, the fungi release hundreds of spores, each capable of infecting another pear psylla.

"We're testing these pathogens in the field this spring," says Puterka. "If our results are what we expect, we'll seek commercial development so the pathogens can be made available to pear growers."


KEITH WELLER

Head count: Inventorying pear psylla that survive on a resistant pear plant, entomologist Gary Puterka also checks for nymphal development. (K5313-8)

Puterka thinks it would not be difficult or expensive for these fungi to be produced commercially by private industries involved in developing biological pesticides. Since growers already spray with a dormant oil in the spring, Puterka says it would be very easy for them to incorporate the fungal spores into their current spray program.

Or Perhaps Parasites or Predators?

Parasites are also being investigated as a means to control pear psylla. The parasite most common to the insect on the West Coast, *Trechnites psyllae,* wasn't found during a recent survey that Puterka conducted on the trees at Kearneysville.

What he did find was a parasite tentatively identified as a *Psyllaephagus* species. Insects infested with this parasite exhibit bizarre behavior. "Parasitized insects would just walk right off leaves and down the tree trunk and hide under cardboard we had wrapped around the tree," he says. "They were very agitated and disoriented." More research is planned on pear psylla parasites.

Since pear psylla also have several predators, planting ground covers between tree rows to attract them could provide a measure of control. While Kentucky 31 tall fescue is a standard orchard floor cover in most of the Northeast, it provides a poor habitat for psylla predators such as lady beetles, pirate bugs, and lacewings. So Puterka is experimenting with perennial crops like clovers to attract aphids and other insects that would support the predators.

"Compared to Kentucky 31, clover attracted about 10 times more aphids to feed the lady beetles, whose numbers increased significantly. As the number of predators increases and their food supply decreases, we hope the predators will then move into the pear trees to feed on pear psylla," he says.

Another season's data is needed to see how the increased number of predators affects pear psylla populations.

These methods could all be used together in an integrated pest management program, Puterka explains. The sugar-ester and fungal pathogens would control the pear psylla, while sparing its natural enemies and allowing them to become well established. "Insects have an innate ability to adapt themselves to single control measures, but they have more difficulty adjusting to the simultaneous onslaught of multiple control measures."

Strengthening Pears' Self-Defense

Some plants are naturally able to defend themselves.

Richard Bell has found this is the case with several pear varieties brought from Eastern Europe by van der Zwet during 1978-80. There is apparently an antagonistic relationship between these varieties and the pear psylla that is not well understood.

To study it further, Puterka is using an electronic feeding monitor connected to the insect to look at the differences in feeding behavior on resistant and susceptible pear varieties.

Although adult pear psylla are only about one-tenth of an inch long and

fairly fragile, Puterka is able to anesthetize them and attach tiny gold wires to their backs.

When pear psylla feed on susceptible pears, a particular waveform pattern appears on a monitor connected to the wires. That waveform is nearly absent during feeding on resistant plants.

Using microsectioning, Puterka and colleagues are trying to find out which plant tissue is touched by the insect's mouthparts at the time of this particular waveform. This will also show which plant tissue is avoided and help isolate the repellent component.

"In analyzing the insect's saliva, we've found pectinase and cellulase, compounds that we know break down plant cell structures," Puterka says.

And scientists are also studying how the pear psylla affects pear tree physiology: Just how and why does the tree lose energy as the insect feeds?

An effective management system will combine host resistance with biological control. But a problem in using host-plant resistance is that the insect may eventually develop an ability to overcome the resistance.

In each new generation, naturally occurring mutant insects—members of a new race or biotype—may survive. This new biotype is able to feed and reproduce normally on the "resistant" plant, to which it somehow becomes adapted. Over time, its numbers will increase as susceptible nonmutants are killed or suppressed.

To assess this potential for adaptation, Puterka and colleagues at Kearneysville have collected psylla from Oregon, Washington, Michigan, New York, and West Virginia and are currently evaluating them on six different resistant pear cultivars.

And this isn't as easy as it may sound.

To evaluate each psylla collection against each pear cultivar, they count out 20 newly hatched pear psylla

KEITH WELLER

More spores: Trees infested with pear psylla get a shot of fungal pathogen spores from biological technician Sharon Jones. (K5306-18)

nymphs, coax them onto single-haired brushes, and gently move them onto the leaves of a 2-foot pear sapling caged within escape-proof netting.

After that, technicians do a head count every 3 days to assess how many have died and the state of development of surviving psylla.

The saplings—30 in all—represent a single test of six cultivars that have been created by grafting buds from psylla-resistant pear trees imported from Europe. In a pear orchard exposed to unchecked psylla attack, the parent trees were left undamaged. But perhaps that's not so surprising, for their fruit are small and have poor texture and flavor.

Now, the trick will be to discover what feeding deterrents or other resistance factors are in the plant tissue, which genes regulate their expression, and how to transfer these genes into commercial pear varieties.

"So far, we've found some significant variations in survival and development time among the pear psylla populations," Puterka says. "However, several resistant cultivars were effective against all psylla populations."

From a Grower Perspective

Chris Baugher has first-hand experience with the pear psylla. He grows fresh-market pears on 10 acres in Aspers, Pennsylvania.

"This pest has cost us money," he says. "Honeydew deposits from the pear psylla made some of our fruit unmarketable last year."

Controlling the insect is a real problem, Baugher says. The number of times an orchard can be sprayed is regulated by the government. And the pest seems to be able to develop resistance so quickly that growers use an insecticide for only one season, then try something else the next. This gets expensive and frustrating. Action by the Environmental Protection Agency to ban many insecticides is leaving even fewer choices for growers.

"We'd be willing to try just about anything at this point," Baugher says.

ARS scientists at Kearneysville are optimistic that pear production problems will be solved. Several approaches can act together to control both fire blight and pear psylla while decreasing the pesticide load on the environment.

As the multifaceted research program at Kearneysville bears fruit, orchardists on the East Coast will be able to once again consider growing pears.—By **Doris Stanley**, ARS

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SOY!

It's No Ordinary Bean

Soybeans are practically as much a part of American life as baseball. They're grown today in more than half of the United States. Yet, a hundred years ago, they were virtually unheard of—raised only by a handful of innovative farmers.

Second in a two-part series on soybean production and products.

First domesticated in China more than 4,000 years ago, soybeans spread throughout Asia as they became an important food crop. They got to the United States in the mid-1700's.

Samuel Bowen was granted a patent in 1767 for inventing methods to produce soy sauce, vermicelli, and a dry powder from soybean plants he had grown. But it would be the early 1900's before commercial markets were established and soybeans were grown as a cash crop.

A pioneer in more ways than one, Henry Ford grew soybeans on farmland owned by Ford Motor Company and found ways to use the oil and meal in parts made for his automobiles.

"Now, soy products are found nearly everywhere you look—from supermarket shelves to hog farms—even in the ink on newspapers," says Wilda Martinez, ARS associate deputy administrator for agriproducts and human nutrition sciences. "ARS researchers are developing technologies aimed at increasing markets for U.S. soybeans."

Across the nation, scientists are looking for new ways to use the soybean's oil, meal, and hulls.

Last year, researchers at the National Center for Agricultural Utilization Research (NCAUR) at Peoria, Illinois, teamed up with an Iowa technology transfer company to reduce the time it takes to identify soybeans by their fatty acid profile. ARS and MBS, Inc., in Ames, are continuing development of a calibration for near-infrared instruments to determine if soybean seeds contain high or low levels of saturated fatty acids. The profile is indicative of the quality of oil that will come from the seed.

If successful, this calibration could provide information about the fatty acid content of single soybean seeds. MBS plans to market the calibration to soybean breeders to shorten the time it takes to develop improved or specialized soybean varieties.

KEITH WELLER

Taste testing: French fries cooked in low-linolenic-acid soybean oil by food technologist Kathleen Warner (left) and technician Linda Parrott are ready for sensory panel experts. (K5244-l)

"With this technology, soybean breeders could potentially screen a seed in 2 minutes, compared with 6 hours for current analytical methods," says James F. Cavins, who led the project at the Peoria center. Before he retired from government service this year, Cavins said that scientists at the Peoria center analyze about 25,000 seed samples each year for soybean breeders at state universities and other public institutions.

Soy Oil—the Big Squeeze

"Extracting oil from some shipments of soybeans may be like trying to get blood from a turnip," says Gary R. List, an NCAUR chemist. "Yet, there may be no problem at all with a practically identical soybean shipment.

"It's the prior handling that makes the difference," he says. "A refining loss occurs when soybeans are handled roughly before reaching the processor."

List and colleagues have found that an enzyme called phospholipase D is the main culprit in soybean oil refining losses. It interferes with degumming—the first step in refining. [See "Enzyme Causes Soybean Oil Refining Loss," *Agricultural Research*, February 1991, p. 18.]

And if any product can boast that it has come a long way, it's soybean oil—used both in foods and for cooking them. Health-conscious people in the 90's are turning to soybean oil because it's cholesterol-free, low in saturated fat, and high in polyunsaturates that help lower serum cholesterol.

Today, soy oil is the most widely used cooking oil at home, in fast-food restaurants, and in prepared food products. It's used in a variety of food products including salad dressings, mayonnaise, margarine, shortening, coffee creamers, frozen dinners, beverage mixes, cookies and crackers, breakfast cereals, soups, sauces, as well as cooking oil.

Genetic diversity: Seeds from the National Soybean Germplasm Collection housed at Urbana, Illinois, show a wide range of colors, sizes, and shapes. Photo by Scott Bauer. (K5267-07)

KEITH WELLER

Hot on the press: Chemist Sevim Erhan uses a heat saddle to check the drying time of a heat-set, soybean-ink test print. (K5251-15)

This widespread use is possible thanks to more than half a century of NCAUR research on flavor preservation and storability of soybeans.

In the 1940's, most soybean oil tasted something like paint, according to retired ARS chemist Herbert J. Dutton. So he and other ARS researchers in Peoria started standardized taste tests for vegetable oils.

Picking up where her predecessors left off, food technologist Kathleen Warner has trained a 20-member panel of flavor experts, whose evaluation methods have become recognized as the quality standard for fats and oils.

Information from these sensory evaluations is ultimately used by soybean breeders to develop new varieties and validate the results of their breeding programs.

ARS and breeders at several state universities have been able to genetically manipulate the seed to produce beans with lower linolenic acid content. This unsaturated fatty acid found in vegetable oils contributes to off-flavors when exposed to air or heat.

Sensory panel tests on genetically modified soybeans have shown that potatoes fried in oil from these new soybean varieties taste better than potatoes fried in standard oils.

"The passing of 50 years hasn't made soy oil older—just better, in the sense that today its taste is neutral," says Warner. "It doesn't mask the taste and flavor of foods."

But another big problem with cooking oils is the odors they give off during high-temperature frying. Warner says linolenate-containing soybean and canola oils can produce fishy odors.

In the 1950's, researchers thought it impossible to change the linolenic acid content of soybeans by means of plant breeding.

So, for years, processors hydrogenated—that is, bubbled hydrogen gas through—soybean oil to prevent the breakdown of linolenic acid. For the most part, industry still relies on mild hydrogenation to produce cooking oils, margarines, and shortenings.

But hydrogenation adds about $200 million a year, or about a half cent per pound, to the cost of oil processing, according to Timothy L. Mounts, who is in charge of the NCAUR's Food Quality and Safety Research Unit.

As an alternative, "breeders have successfully used genetic modification to lower linolenic acid to a point that off-odors are no longer a problem in some new soybean varieties," he says.

And Peoria researchers also helped bring other important changes to the U.S. soybean industry by showing that hydrogenation could be eliminated for soybean salad oil and the oil packaged in plastic, rather than glass bottles. "Eliminating salad oil hydrogenation and switching to plastic bottles has saved industry about $310 million a year for the past 8 years," says Mounts.

Hey, There's Soy Oil in the Ink!

The latest news in the soy ink story is that the pigment carrier in 100-percent soy ink has been shown to biodegrade almost twice as completely as ink made of soy oil and petroleum resins, and more than four times as completely as standard petroleum-based ink. NCAUR chemists Sevim Erhan and Marvin O. Bagby conducted the degradability studies.

The research team recently completed development of black soy inks for two types of printing processes—sheet-fed and heat-set printing—having previously developed black and color inks for lithographic newspaper printing.

Sheet-fed printing is used mostly for books and can be done on either coated or uncoated paper. During the sheet-fed process, one sheet of paper is pulled through the printing press at a time. It is often used for better quality products.

The type of printing used to make glossy advertising supplements and high quality magazine pages—a heat-set process—can now be done using another of ARS' soy inks. This is one process in which soy inks haven't performed well in the past. "That's because the soybean oil does not evaporate or dry quickly in the oven used to set the ink on the paper," says Erhan.

The scientists chemically modified the oil to speed the drying process.

NCAUR first became involved with soy oil ink in 1987, when the American Newspaper Publishers Association (ANPA—now the Newspaper Association of America) asked ARS to help meet an industry goal of formulating a newspaper ink that would be stable in price, cost-competitive with petroleum-based inks, and mainly derived from a renewable resource.

Earlier ANPA efforts had already led to development of a hybrid ink containing soybean oil mixed with petroleum resins, the basic formula for which was accepted and adopted by ink manufacturers.

In less than a year of experimenting with oil and pigments, Erhan and Bagby developed a 100-percent soybean oil-based ink to be used for lithographic newspaper printing that's cost-competitive with conventional petroleum-based news inks.

Lithographic newspaper ink is a paste-type ink; ARS chemist Richard Madrigal and Bagby are now trying to make liquid soy inks for another type of newspaper printing—flexographic printing. At this time, less than 5 percent of the nation's newspapers use the flexographic process.

New news ink: Water/soy oil-based flexographic ink formulations like these being evaluated by chemist Richard Madrigal may replace petroleum-based inks. (K5246-6)

KEITH WELLER

"An advantage our four soy-based inks (lithographic, heat-set, sheet-fed, and flexographic) will have over most other current industrial printing inks is that they don't contain petroleum solvents or other volatile organic compounds," Bagby says. "VOC's are facing more regulatory controls because of the environmental concerns of federal and state agencies."

Thus, the demand for printers to use more soy inks is greater now than ever. Many states, including Illinois and Iowa, have passed legislation requiring state printing jobs to be done exclusively with soy inks. Erhan and Bagby are confident the ARS soy ink could fill the bill for this important use of soybean oil.

If complete conversion to 100-percent soy ink occurs, about 2.5 billion pounds of soybeans—or 500 million pounds of soy oil—will be used to supply the news ink market. And other applications of the soy ink technology could lead to markets in excess of 1 billion pounds of soy oil.

Oil To Burn and To Spread

Soy oil is being studied by NCAUR scientists as an alternative to diesel fuel. "Soybean and other common vegetable oils have roughly 90 percent of the energy content of diesel," says Bagby, "and they don't have the noxious exhaust emissions of petroleum fuels. However, we hope to decrease emissions even further."

But before soybean oil can replace diesel, several hurdles must be cleared. The viscosity of soybean oil is 10 to 15 times higher than diesel fuel, which interferes with fuel injection and adds to incomplete combustion. In addition, volatilities are low, and that means that unburned fuel builds up on engine parts and in the lubricating oil.

Much of the current research related to soy oil's use as a fuel focuses on resolving low-temperature deficiencies and understanding how vegetable oils react when subjected to high temperature and pressure before burning begins. So scientists are looking for a compound that can be added to soy oil to serve as a catalyst. Ideally, it would become activated only in the combustion chamber and cause a more desirable chemical reaction, thereby improving combustion and decreasing emissions.

"There's still a way to go with our work before soy oil can be widely used as diesel fuel," says Bagby. "But if we can 'grow our own fuel' and become less dependent on nonrenewable resources, it will be worth the wait."

In the meantime, researchers are finding that soybean oil may replace petroleum and other substances used as a spreading agent, or adjuvant, when herbicides are applied to crops.

"Soybean oil mixed with certain herbicides promises to increase the effectiveness and consistency of the herbicides," says Loyd M. Wax, the agronomist who heads the ARS Crop Protection Research Unit at Urbana, Illinois. "We've had a fair amount of success against giant foxtail and selected broadleaf weeds."

Wax and colleagues have been able to lower postemergence herbicide applications to about 5 gallons per acre—down from the usual 10 to 20 gallons.

These field tests are patterned after successful trials by Chester G. McWhorter (retired) and other scientists in the ARS Application Technology Research Unit at Stoneville, Mississippi. Those scientists have reduced herbicide application rates to 1 gallon per acre with little to no effect on efficacy, when soybean oil is used as an adjuvant. [See "Farmer-Friendly Herbicide Applicator," *Agricultural Research,* February 1993, p. 11.]

Ultra-low volumes of herbicide are applied using a specially designed spraying concept first dubbed the "T-miser." The ULV sprayer was developed by Floyd Fulgham and James Hanks, agricultural engineers at Stoneville.

Wax says differences in results from the Urbana and Stoneville field tests may be due to several factors, including different weed species, climates, and application equipment.

New Uses for Soy Protein

ARS researchers are using a variety of scientific methods including chemistry, biotechnology, and genetics to find new uses for soy protein. In fact, soy is an excellent source of protein, but it contains naturally occurring compounds that can prevent people and animals from getting the maximum benefit from it.

So makers of soy-based foods like diet shakes, baby formulas, or animal feeds must use heat or other means to deactivate the troublesome compounds, known as trypsin inhibitors. There are two basic types of these inhibitors: Kunitz and Bowman-Birk, named for researchers Moses Kunitz and Donald E. Bowman and Yehudith Birk.

But heating is costly, says David J. Sessa, an ARS chemist at Peoria. New techniques for processing soy meal could cut the high energy costs, as well as add to soy's value in world markets.

Sessa has developed a pure protein model system to demonstrate to industry how heat affects the whole soybean.

"Once we know precisely how much heat is needed, we can alter proteins and design them with specific functional properties," Sessa says. "These newly modified proteins could then be incorporated into new foods, feeds, or industrial products."

In earlier studies, Sessa inactivated trypsin inhibitors by treating soy with sodium metabisulfite, a food additive used in small amounts in processing frozen french fries and in winemaking.

"It's an inexpensive way to inactivate the trypsin inhibitors," he says.

In 1990, Sessa conducted a study with Chhorn E. Lim, a biologist in the ARS Tropical Aquaculture Research Unit at Oahu, Hawaii. They fed shrimp diets containing soymeal in place of some protein that would otherwise have come from fishmeal or other marine animal sources.

The study was the first to demonstrate that marine shrimp probably aren't as sensitive as other aquatic species to soy trypsin inhibitors.

What, No Trypsin Inhibitors?

Developing soybean varieties lacking some or all trypsin inhibitors is another approach to overcoming the processing problems caused by the compounds. ARS and University of Illinois scientists have pinpointed plants that may lead to a futuristic variety that would be nearly free of the unwanted inhibitors.

And they now have tools to screen soybeans for both the Bowman-Birk and Kunitz inhibitors. Specially designed proteins—monoclonal antibody probes—seek out and bind to the inhibitors, enabling researchers to detect them.

Each probe specifically binds to one particular inhibitor. ARS researchers David L. Brandon, Anne H. Bates, and colleagues developed the probes in their laboratory at the ARS Western Regional Research Center, Albany, California.

Using the probes, Theodore Hymowitz, a geneticist at the University of Illinois, Urbana, recently screened more than 13,000 soybeans and discovered that some wild relatives of domesticated soybeans apparently have

KEITH WELLER

Environmentally friendly: Ultra-low-volume herbicide application methods developed by ARS plant physiologist Chester McWhorter (now retired) and colleagues could significantly reduce the use of agricultural chemicals. (K5287-4)

significantly lower amounts of the Bowman-Birk inhibitor.

Earlier work targeting the Kunitz inhibitor resulted in a soybean variety dubbed "Kunitz" being offered to farmers in 1991.

A hardy soybean with only a trace of the Kunitz-type inhibitors, it was developed by Hymowitz, Richard L. Bernard, now retired from ARS, and Charles R. Cremeens, who is with ARS at Urbana.

Hymowitz envisions that it may be possible within the next 10 years or so to combine the low Bowman-Birk wild plants with the Kunitz variety to yield a ultralow-trypsin-inhibitor soybean.

And until then, the low-Kunitz bean offers an environmental advantage: Though it still contains the Bowman-Birk inhibitors, it requires less energy to inactivate them.

When steam-heated for 20 minutes at about 250°F, flour from a standard commercial variety still had 20 percent of its inhibitors left, reports Mendel Friedman of the ARS team at Albany. But flour from the low-Kunitz beans had near-zero levels of active inhibitors.

Transforming Soy Proteins

ARS researchers at several locations are hoping to expand markets for soybeans by looking at new ways to use soy protein in foods, feeds, and industrial products.

Unfortunately, nature puts proteins together in a way that's not always suitable for modern food technology.

At NCAUR, scientists are looking at the molecular composition of important soy proteins and studying the effects of chemical, mechanical, and heat processing on these proteins.

"If we change the proteins' physical forms, we can enlarge the range of options for using heated proteins in many food and industrial applications," says chemist Walter J. Wolf.

One of the major obstacles to using soy protein in food products is its solubility. Wolf is tackling the problem by attaching monosaccharides—such as glucose—to glycinin, the major storage protein of soy.

"If we can make soy proteins more soluble in acidic environments, it may be possible to develop carbonated soft drinks that are protein enriched," says John A. Rothfus, a chemist and also leader of the project.

KEITH WELLER

Quality counts: Chemist Gary List checks soybeans. (K5256-2)

"Proteins can do many things that starch and gum can't do, especially when processing and developing products with special characteristics, such as moisture resistance," says ARS chemist Frederick F. Shih at the Southern Regional Research Center in New Orleans, Louisiana.

Shih has found a way to make plastic films and coatings from soy proteins. The films and coatings can be made into moisture-resistant food packaging materials.

Controlling the genetics of the soybean plant may also change the composition of its proteins, allowing them to be more easily used in additional food products.

Niels Nielsen, an ARS geneticist at Purdue University, is using genetics to make better soybean curd, or tofu, a staple in the Asian diet that seems to be increasingly popular with diet-conscious Americans.

Tofu is a high-protein product made from soybeans grown for food uses. Whitish in color, it has a very bland flavor, a consistency similar to firm custard, and a versatility that allows it to be prepared in many ways.

"The problem is that not all soybeans make good tofu," says Nielsen. "And with the surging popularity of tofu, there is a need for beans tailored for just that use."

Some soybeans, particularly those slightly low in protein, make tofu that is too soft and fragile—prone to mechanical damage during handling.

Other soybeans give tofu undesirable tastes and aromas that can be described as grassy, beany, buttery, or astringent. Still other beans produce curd that is pale yellow in color instead of the white preferred by many Asians; because soy milk and tofu turn yellow as they age, the off-color is undesirable.

Nielsen's goal is to make tofu a more attractive source of protein by eliminating lipoxygenases, the enzymes that produce the beany off-flavor sometimes associated with tofu.

"Evaluations by trained taste panels have shown that the beany flavor is reduced by eliminating one or more forms of the enzyme from the soybean seeds," he says.

The improved flavor trait was found in very "unadapted" soybean lines—in this case, ones with green and black beans. Now, the genes for improved flavor have been bred into a soybean variety with good agronomic qualities.

"The result is a better tasting soybean that also has improved agronomic traits," says Nielsen. "Although products made from these beans have the undesirable pale-yellow color, the germplasm from this line will be very useful in further breeding programs."

A small-scale tofu production line has been set up in Nielsen's laboratory to help quality-test tofu and soy milk from various soybeans. However, the scientists are encouraging commodity organizations to assume responsibility for performing this service for plant breeders.

Patents protecting the low-lipoxygenase traits are in force both in the United States and Japan.

Improving Soy's Digestibility

Humans and animals often have problems digesting some forms of soy. Using the tools of biotechnology, NCAUR chemist Tsung Min Kuo is trying to make soy products easier to digest.

"Soybeans produce a class of complex carbohydrates known as raffinose sugars that are largely indigestible by humans and animals," says Kuo. "These sugars decrease feed efficiency in farm animals that are fed more than 90 percent of domestic soybean meal. In humans, they produce gastrointestinal effects that discourage soybean consumption."

In 1988, University of Minnesota scientists found that removing these sugars increased the amount of metabolizable energy derived from the soymeal in the feed. So Kuo decided to search for soybean seed naturally low in raffinose sugars. More than 1,000 seeds from the ARS Soybean Germplasm Collection and from breeders have been screened.

Now, Kuo and his colleagues are also at work genetically modifying soybeans to reduce raffinose sugars.

"We have isolated a small section of a gene that codes for an enzyme called galactinol synthase that is needed for the production of raffinose sugars," Kuo says.

The researchers are continuing studies on other soybean enzymes that could perhaps be modified so as to inhibit raffinose sugar production. One of the techniques they use is antisense—a relatively new biotechnological tool that tricks a gene into not doing what it's programmed to do.

In this case, the objective is to try to block the genes responsible for making the enzymes needed to produce raffinose sugars.

Having access to processed products with little or no raffinose sugars would significantly spur consumer interest in soybeans.

But several foods developed years ago from soy protein combined with other commodities have already contributed greatly to improving world nutrition. Corn-Soy-Milk (CSM) is just one example of a high-protein, soy-based blended food product developed at NCAUR that has enjoyed extended use overseas.—By **Marcie Gerrietts,** formerly with ARS, **Linda Cooke,** and **Marcia Wood,** ARS.

To contact scientists mentioned in this article, write or telephone Ben Hardin, USDA-ARS-NCAUR, 1815 N. University St., Peoria, IL 61604; phone (309) 681-6597, fax (309) 681-6690. ◆

KEITH WELLER

Breakdown: Technician Wanda Brown adds microorganisms to unpigmented soy ink to study the ink's rate of biodegradation. (K5257-7)

Heat-Processing Soybeans for Ruminants

To roast, or not to roast, hasn't been the question. Instead, soybean processors in the nation's leading dairy state have wanted to know how long—and at what temperature—to roast soybeans, to gain the most nutritional benefit for dairy cows.

Answering those questions has been a goal of ARS scientists at the U.S. Dairy Forage Research Center in Madison, Wisconsin.

Under the direction of Larry D. Satter, the researchers have demonstrated the benefit of feeding properly heated soybeans to dairy cows. The payoff has been to the state's soybean producers, who have almost doubled their acreage in the last 3 years, partly in response to the new market developing for their soybeans.

"Feeding roasted whole soybeans is becoming increasingly popular among dairy producers who want to supplement their cows' diet with a palatable protein and energy source," Satter says.

Soybeans are a good source of concentrated calories for lactating cows because of their oil content. Soybeans also contain a large amount of protein rich in lysine, an essential amino acid needed by dairy cows to make milk.

That's good news for dairy producers because a cow's digestive system can be a big protein waster. Bacteria in the rumen—the first compartment in the four-part stomach—break down protein, as well as make it. But the bacteria often break down more protein than they make, resulting in a costly waste.

"The challenge is to get feed protein to bypass, or resist, breakdown and be available later for absorption in the small intestine," says Satter.

Heating soybeans has been shown to increase the amount of bypass protein.

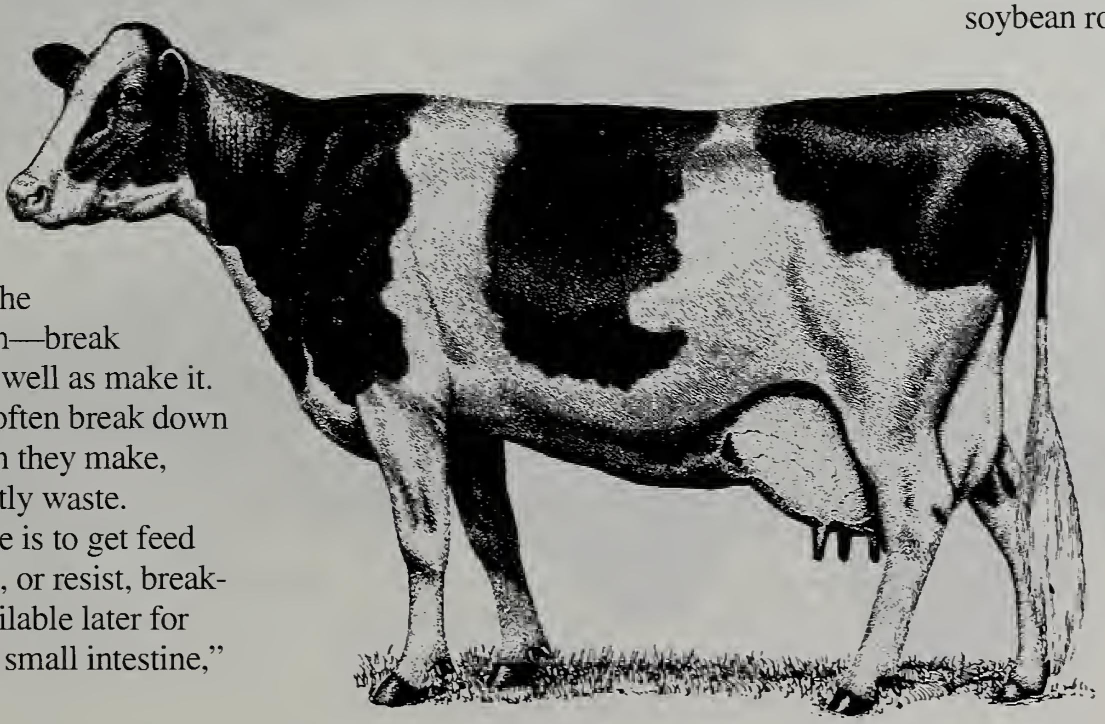
But dairy farmers, who may pay from $50 to $70 more a ton for roasted soybeans, don't always get their money's worth because of improper roasting methods. It's been common in the past for processors to underheat soybeans, because information on how much heat to use hasn't been available.

And while underheating fails to convert the protein in the soybean seed to bypass protein, too much heat makes the protein largely unavailable. "Either way, cows are nutritionally robbed and producers throw money away on roasted beans that are no better than raw soybeans," Satter says.

About 6 years ago, he and co-researchers at the center began exploring what happens when soybeans are roasted. They wanted to know how much heat is really needed.

So they tested soybeans heated to varying extents for bypass protein and for the amount of lysine that would be nutritionally available in the small intestine. Their experiments involved rumen bacteria, young rats, and lactating cows.

They found the best treatment to be heating beans to 295°F and holding them for 30 minutes before cooling.



Maintaining that temperature for one-half hour lets the heat penetrate the beans. It also allows enough time for the protein to react with sugar to form a complex that's more resistant to rumen breakdown.

But the real proof of the cooking came when the researchers fed properly roasted soybeans to more than 100 Holsteins; they gave from 3 to 5 pounds more milk per cow daily.

Taking the work one step further, the researchers began developing a standard that could be used to show how well soybeans had been roasted. They used as a baseline a test known to the soybean meal industry as the protein dispersibility index, or PDI, which was calibrated to animal feeding experiments.

The research showed that a PDI value of 9 to 11 indicates optimum roasting for bypass protein development. Higher values are indicative of suboptimal processing.

The PDI index is being used by Dairyland Laboratories in Arcadia, Wisconsin, and whole-bean processors now have a standardized means for measuring product quality.

To round out this work, agricultural engineers Richard G. Koegel and Timothy J. Kraus are building a better soybean roaster. This machine is expected to be less costly and more energy efficient than roasters currently available.—By **Linda Cooke,** ARS.

Larry D. Satter, Richard G. Koegel, and Timothy J. Kraus are located at the USDA-ARS U.S. Dairy Forage Research Center, 1925 Linden Drive West, Madison, WI 53706; phone (608) 263-2030, fax (608) 264-5275. ◆

Gynogenesis: Shortcut to Superior Catfish

Imagine being able to accomplish 6 to 9 years of research in a half or a third the time.

That's what scientists in the ARS Catfish Genetic Research Unit at Stoneville, Mississippi, are doing.

Using a process called gynogenesis—for the first time in catfish—they're speeding up development of stocks of fish with an assortment of desirable traits. What they do is collect semen from selected male catfish and expose it to ultraviolet light, which destroys the DNA and sterilizes the spermatozoa but does not affect their motility.

Then, they obtain eggs from females that have been stimulated to spawn by behavioral interactions with nonsterile males cohabiting their fish tank. Fertilization of the eggs is performed externally by the scientists.

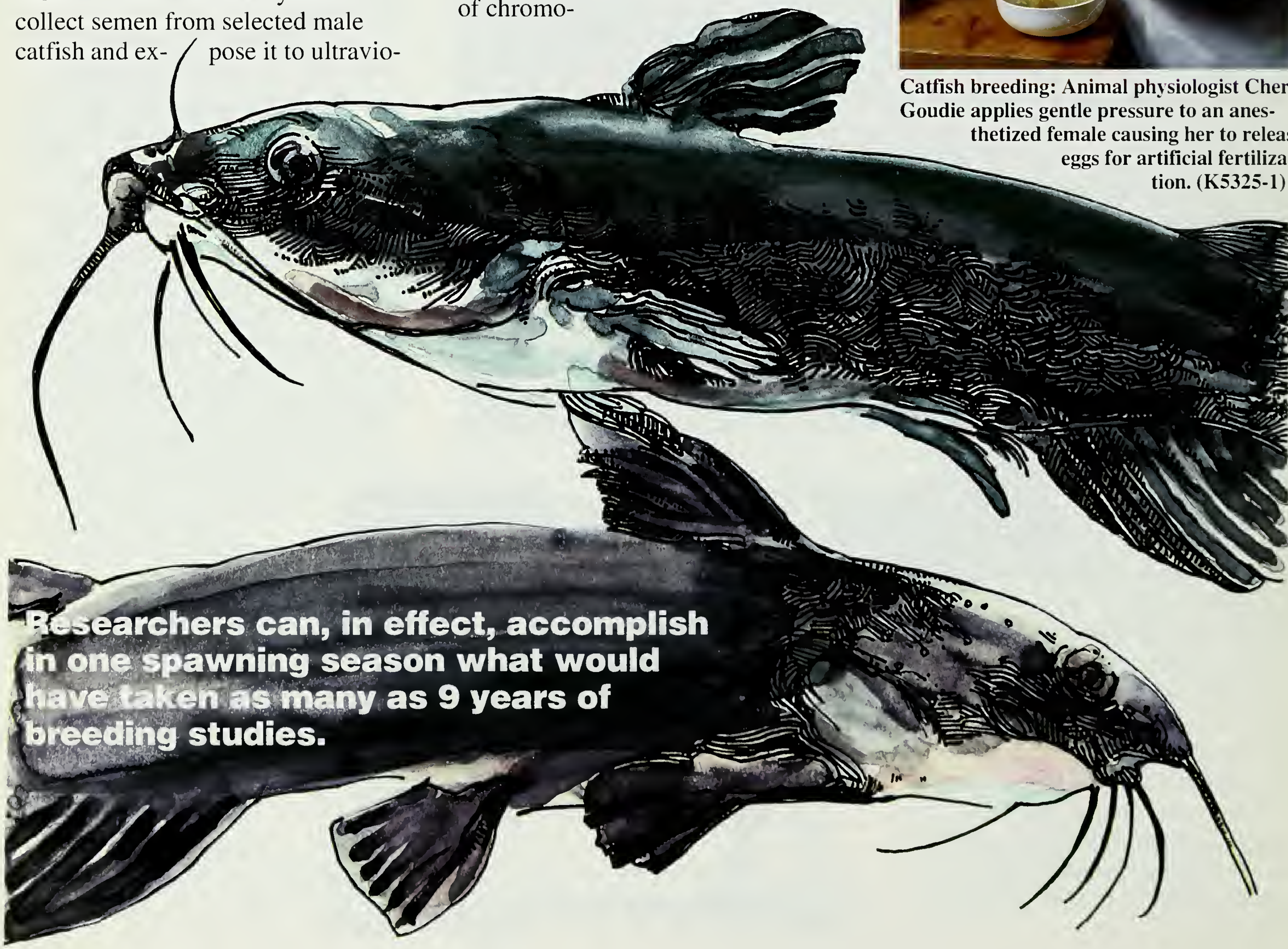
Since the spermatozoa used are sterile, they pass along no genetic information to the offspring.

But eggs fertilized with sterile sperm contain only half the genetic information, stored in chromosomes, that is necessary for normal development. So the embryos do not survive.

To restore a full complement of chromo-

DAVID NANCE

Catfish breeding: Animal physiologist Cheryl Goudie applies gentle pressure to an anesthetized female causing her to release eggs for artificial fertilization. (K5325-1)



somes, the Stoneville scientists treat the fertilized eggs with pressure shocks or exposure to hot or cold water temperatures. These treatments prevent the loss of a set of female chromosomes which would otherwise be eliminated during cell division to make room for insertion of the male chromosomes. Thus, the gynogenetic eggs acquire the normal amount of genetic material, but all of it is contributed by the female.

"This combination of genes," says reproductive physiologist Cheryl Goudie, "allows the expression of many harmful or lethal recessive genes that would normally be hidden, and it greatly reduces offspring survival. But the gynogenetic fertilization process also decreases genetic variability within those offspring that do survive, enabling us to more easily select and enhance a particular trait. So we can use gynogenesis to inbreed fish with desirable features faster than when we mate siblings generation after generation."

Although the techniques of gynogenetic reproduction take just a few minutes to perform, the fertilized eggs must still be allowed to hatch and the hatchlings to grow for 3 to 4 years, to reach sexual maturity and reproduce.

Even so, the combination of traits achieved in a single generation of gynogenetic offspring is comparable to the result of two or three generations of conventional inbreeding of mated siblings. Thus, researchers can, in effect, accomplish in one spawning season what would have taken as many as 9 years of breeding studies (three fish generations, each taking at least 3 years to mature and mate).

"When grown, the gynogenetic fish can be used as a brood stock to produce second-generation gynogenetic offspring that are all clones of the mother, and the process can be continued for as many generations as you want," Goudie says. "This exact genetic replication allows us to study environmental effects on catfish without having to factor in genetic variability."

Goudie and colleagues are using gynogenesis to produce families of catfish with selected desirable traits that include tolerance to poor water quality, disease resistance, more efficient feed conversion, and improved growth rate and body composition.

Gynogenesis can produce families of catfish with desirable traits that include tolerance to poor water quality, disease resistance, more efficient feed conversion, and improved growth rate and body composition.

Once the researchers successfully reproduce selected traits in subsequent gynogenetic generations, they cross the inbred lines with other catfish strains that show additional desirable traits. They know the importance of restoring genetic variability—or hybrid vigor—within the species, to reduce its vulnerability to disease or other problems.

One serious drawback of gynogenetic catfish reproduction has been that all of the offspring produced are females. Until recently, the only way to propagate gynogenetic lines has been by crossing them with non-gynogenetic males.

Now, Goudie and the other Stoneville scientists researching sex-control mechanisms in catfish have developed females with a male sex genotype. These females produce both male and female gynogenetic offspring, thus allowing crossbreeding to occur within and among gynogenetic lines.

An added bonus is that gynogenetic males, when mated with normal females, produce only male offspring. Since male catfish grow faster than females, commercial farms using these gynogenetic "supermales" for broodstock would have an economic advantage over farms using males that produce mixed-sex offspring.

New, improved catfish lines developed through gynogenesis should eventually be available to aquaculturists—and sooner than if conventional breeding programs were used. "But we're still talking years down the road," says Goudie.

"We are currently conducting studies to optimize sperm irradiation and the timing of egg shock treatments, to improve our yields of gynogenetic offspring," she says. "We hope to have, within a few years, the knowledge needed about induced gynogenesis to develop domesticated catfish lines with the traits most desired by commercial producers."—By **Marcie Gerrietts,** formerly with ARS.

Cheryl Goudie is in the USDA-ARS Catfish Genetics Research Unit, Jamie Whitten Delta States Research Center, Stoneville, MS 38776; phone (601) 686-5460, fax (601) 686-9406. ◆

Getting Research to Users—A Coordinated Approach

"Science is built up with facts, as a house is with stones. But a collection of facts is no more a science than a heap of stones is a house," said Jules Henri Poincaré (1854-1912) writing in *La Science et l'Hypothèse* in 1908.

Much research has been conducted during the past century to help farmers and ranchers make a profit and keep them in the business of growing our food. But in some cases, the individual research findings represented little more than single stones. What was needed, as Poincaré wrote, was many stones that fit together to form a house.

A drop in farm income affects more than farmers. When farmers don't have money to spend, local business owners suffer financially; so do workers at tractor assembly plants in the Midwest, and so on.

Because many farmers and agricultural communities are finding it increasingly difficult to avoid financial trouble, a technology transfer team has been created to provide a complete information package to assist them in making the best possible farming and business decisions.

Cooperators include the Agricultural Research Service, Colorado State University's Agricultural Experiment Station and Cooperative Extension, private accountants, bankers and other agricultural financiers, and Northeastern Junior College in Sterling, Colorado.

In the past, technology was generally presented to farmers in a piecemeal fashion. It was up to the farmers to fit the individual pieces together. So growers were often the first to discover how all the pieces interacted and to see the results and problems.

SCOTT BAUER

TRIM and fit: Extension agent Wayne Cooley, ARS agronomist Randy Anderson, and farmer Gilbert Lindstrom work together as a team to figure the best methods for growing wheat in a dryland cropping system relying on a wheat/corn/fallow rotation. Timely and appropriate weed-control measures are critical to conserving scant soil moisture. (K5230-10)

Now it is possible to get a total planning package that shows the effects of different and complex management decisions without expensive, and sometimes ruinous, trial-and-error farming.

"Looking at field station research data is one thing; applying the data to our particular farm is another. We need that intermediate step where we can see if new practices will really be feasible for us, from a production standpoint," says Gilbert Lindstrom, a diversified farmer from Sterling. Lindstrom is one of the original members of the TRIM (Technology Resource Integrated Management) team that transfers scientific knowledge for on-farm use.

TRIM aims to make the most profit for farmers while minimizing change to the surrounding environment—a truly sustainable approach to farming and ranching.

TRIM deals with every aspect of agricultural production—from securing bank loans for operating capital to marketing finished products in a global economy. The computer models under development are expected to be easy to use, so farmers will be able to run various scenarios themselves.

"We have 8 farmers now working with 30 team members in the project. We'll add more farmers and members as we gain more knowledge," says James R. Welsh, director of ARS' Natural Resources Research Center in Fort Collins, Colorado. Welsh is the leader in providing relevant research to the working groups. He provides findings from all sources—federal, state, and private institutions. The technology is coming from ARS and university colleagues.

"The program is showing that scientists are real people who are willing and able to share their knowledge with others who will benefit most from having it," says Thomas J. Army,

director of ARS' Northern Plains Area, Fort Collins.

"What worked in farming in the 1940's, or even as recently as 10 years ago, is not working today. Many changes have forever altered the way U.S. agriculture operates.

"We are more aware of dangers that chemicals pose to farmers who apply them and to rural and urban citizens who drink water and eat foods from treated fields. We are involved in stiff competition with farmers in other countries. All these factors are part of the TRIM team's program. I'm confident that the group will show us how to make U.S. farming more profitable and environmentally acceptable," he says.

"We need to minimize farmers' risks in using money—a needed but limited resource—while maximizing their profits," says Douglas Kinzie, loan officer at Century Bank in Sterling, Colorado. Kinzie services commercial loans to area farmers and is a program participant. "We hope to get useful technology to all people who provide support to agriculture and see them continue working together."

TRIM is governed by a board of directors representing the various team participants. A. Wayne Cooley, Logan County extension agent, is the program facilitator who coordinates and transfers technology to those who need it. He is supported by management teams that are assigned to individual cooperators.

Farmers involved in the demonstration project are diverse. Some are primarily livestock producers, while others grow irrigated crops or dryland wheat; some producers combine production systems. "By including so many systems, we add flexibility to agricultural production. We can demonstrate how combining certain operations results in more income some years, saves soil, reduces pesticide and fertilizer use, and cuts irrigation water needs," says Welsh.

"Just as a test drive is the best way to show a vehicle's handling qualities, demonstration is the best way to get agricultural technology to farmers. And transfer of today's technology is more complex than it was 50 years ago. Back then, educators could demonstrate how a single change, such as planting hybrid corn, could improve farm income. Today, we must often use computers to sift through thousands of facts, to arrive at the most reasonable alternatives for complex production systems that are made up of many component packages," says Welsh.

> TRIM aims to make the most profit for farmers while minimizing change to the surrounding environment.

One package improves cropping systems on lands that have traditionally been wheat-fallowed. Under wheat-fallow, growers let land idle every other year so that moisture from limited rain and snowfall accumulates in the soil to support a wheat crop the following year.

But researchers at ARS' Central Great Plains Research Station, Akron, Colorado, now know that enough moisture accumulates to support crops for 2 subsequent years. They have shown that growers can successfully grow wheat and then corn after 1 fallow year. And they've shown they can include safflower as one of the crops. These alternative cropping systems can increase farm income by 30 percent or more.

Another package addresses growing alternate crops—those that historically have not been grown in the area, such as edible legumes and oilseed crops.

A third package includes research findings from the High Plains Grasslands Research Station in Cheyenne, Wyoming. It helps cattle producers select the best grazing system for their ranches and can also determine the profitability of re-seeding to different grasses to increase forage yield and cattle weight gain.

"This is the second year the TRIM team has been functioning. While it is centered on participants in eastern Colorado, our scientists will develop computer models to also help farmers and ranchers on the entire Great Plains," says Lajpat Ahuja, who is in charge of the Great Plains Systems Research Unit at Fort Collins.

Once proven for this project, the computer models will be used to help farmers in other parts of the country who produce different crops and commodities.

The Great Plains Framework for Agricultural Resource Management (GPFARM) systems model project already has scientists and cooperators assessing information needs and concerns of producers throughout the Plains—from Montana to Texas, and from Colorado to Nebraska.

"GPFARM will be a major step forward in bringing researchers together to meet customer needs. The sky's the limit when it comes to developing packages. If there's a need, we can work together to produce it," says Welsh.—By **Dennis Senft,** ARS.

James R. Welsh is at the USDA-ARS Natural Resources Research Center, Crops Research Laboratory, 1701 Center Ave., Fort Collins, CO 80526; phone (303) 498-4227, fax (303) 498-4242. ◆

Strategic Weed Control for the 90's

Before the discovery of herbicides, the only way to get rid of weeds was to pull them by hand or to uproot them by tilling. Today, scientists are taking a new look at field cultivators to learn how they might fit into improved weed control strategies in cornfields.

Herbicides currently account for 85 percent of all pesticides used for producing the top 10 crops in the United States. Of the total herbicide used, more than 80 percent goes on corn and soybean fields.

Reducing this amount would please farmers—they'd save the money spent on chemicals and their application. It would also please people who want to reduce herbicide use to protect the environment.

"We need to find new weed control strategies that effectively balance the use of herbicides with environmental protection," says Edward E. Schweizer, Agricultural Research Service plant physiologist. "I think we can accomplish that by combining tillage implements with computer technology."

Key to this approach will be an expanded version of a model that selects an appropriate weed control strategy to minimize herbicides.

Schweizer originally developed the model in cooperation with Colorado State University. [See "Weed-Free Fields Not Key to Highest Profits," *Agricultural Research,* May 1989, p. 14-15.] Once the scientists include new data collected during a 3-year study near Fort Collins, Colorado, the updated computer model, WEEDCAM, will select several tillage practices—used with or without herbicides—to control weeds in irrigated cornfields.

The cultivation study evaluated three tillage implements, each used without herbicides. Weed populations, crop yields, and net income per acre on these plots were compared to similar plots treated with herbicides that the computer model recommended.

One implement studied was a standard rotary hoe that has 12-inch metal fingers rotating around a shaft when pulled across a field. The hoe breaks the soil surface, displacing many emerging weeds. And corn sustains little damage, because the hoe is used when seedlings either haven't emerged or when plants are large enough to withstand tillage.

SCOTT BAUER

Framed: Evaluating weed-control effectiveness, plant physiologist Ed Schweizer inspects plants just passed over by the spyder (front), torsion weeder, side knife, and spring hoe weeder (back) attachments performing in-row cultivation. (K5226-18)

Another device tested was a conventional row cultivator with small shovels that disturb soil between corn rows and uproot weeds. The third implement, an in-row cultivator designed about 30 years ago, has a series of tools that reach across the crop row and uproot weeds growing in-row between crop plants, as well as weeds growing between rows.

Correct timing of the tillage operation was found to be key to reducing weed populations and increasing crop yields. The rotary hoe worked best when weeds had germinated but not yet emerged from the soil. The row cultivator worked best when inter-row weeds were 6 inches or shorter. The in-row cultivator was most effective when weeds were shorter than 2 inches.

But by using the weed computer model to select appropriate herbicides to use with either cultivator, yields were 30 percent greater and generated about $65 more income per acre compared with in-row cultivation without herbicides.

Compared to standard cultivation without herbicides, the plots that the computer model was used on yielded about 70 percent more corn and generated about $120 more per acre.

"It looks like we'll need a combination of practices to achieve our goals. We cannot switch from using a herbicide-intensive system to one that involves only cultivation, if fields have many weed seeds. We might have to use herbicides for as many as 4 years to reduce heavy weed populations enough to make in-row cultivation feasible for keeping weeds in check," says Schweizer. He plans to incorporate the tillage data into WEEDCAM for further evaluation.—By **Dennis Senft,** ARS.

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Science Update

ARS Licenses Sex-Selection Method

Animal Biotechnology Cambridge, Ltd., of Cambridge, England, received a license to commercialize ARS-patented technology to predetermine gender of farm livestock. That would help dairy farmers obtain more female calves to improve their herds and ranchers obtain more male beef cattle, which grow faster than cows. Sperm cells tinted with fluorescent dye pass through a laser beam that sorts them by whether they hold X (female-determining) or Y (male-determining) chromosomes. After ARS tests with swine, sheep, and rabbits, the company and ARS recently used the method to produce the world's first calves of predetermined sex. *Lawrence A. Johnson, Germplasm and Gamete Physiology Laboratory, Beltsville, Maryland; phone (301) 504-8545.*

To Wheat Growers, MoreCrop Could Mean Less Disease

MoreCrop, a new ARS computer program for Pacific Northwest wheat growers, is now available for $40 through the Cooperative Extension at Washington State University. MoreCrop predicts disease threats and supplies options for countermeasures. It runs on IBM-compatible computers with 4 megabytes RAM and Microsoft Windows version 3.0 or higher. Scientists plan to adapt it for other wheat-growing regions. *Roland F. Line, USDA-ARS Wheat Genetics, Quality, Physiology, and Disease Research Unit, Pullman, Washington; phone (509) 335-3755.*

Putting Cabbage and Broccoli Out to Pasture

ARS researchers have worked out a way for farmers to grow profitable fall crops of broccoli and cabbage on land considered too erodible for anything but pasture. In August, they apply a tiny amount of herbicide to the grass. It doesn't die, but the roots temporarily stop taking up moisture—leaving plenty for the tender, thirsty broccoli and cabbage seedlings transplanted there in early September in narrow, lightly tilled strips of soil. About the time the vegetables are harvested in late October, the pasture grass begins recovering. It will supply forage the following year. *Donald J. Makus, South Central Family Farms Research Center, Booneville, Arkansas; phone (501) 675-3834.*

KEITH WELLER

(K3551-10)

Computer Serves as Electronic Taste Buds for OJ

Processed orange juice could taste more like fresh-squeezed, thanks to a new ARS computer program. It pinpoints the precise mix of 20 flavor components in fresh juice. Manufacturers would use the program to compare this mix with chemical analyses of their processed juices. That will enable them to discover which flavor fractions are needed for the taste of their products to more nearly match fresh-squeezed juice. *Philip E. Shaw, USDA-ARS Citrus and Subtropical Products Laboratory, Winter Haven, Florida; phone (813) 293-4133.*

Pickle Test Adapted to Help Winemakers

Wine taste and quality depend partly on the right balance of acids, sugars, and alcohols. Now, winemakers have a faster, more accurate way to measure 13 of these compounds simultaneously. ARS scientists first developed the method to analyze acids, sugars, and alcohols in pickles, another fermented product. The method uses an improved system of high-performance liquid chromatography. *Roger F. McFeeters, USDA-ARS Food Science Research Laboratory, Raleigh, North Carolina; phone (919) 515-2979.*

Company Licenses Anti-Salmonella Technique

In the future, hot dogs and other meat products should be even less likely to contain salmonella—a major cause of food poisoning—when they leave the processing plant. Difco, Inc., of Detroit, Michigan, has licensed an improved, ARS-patented growth medium for use in tests to ensure that no cells of salmonella bacteria, if present, have survived cooking or other treatments. The new medium must pass rigorous tests at 10 independent laboratories before it can be used by industry. *J. Stan Bailey and Nelson A. Cox, Poultry Microbiological Safety Research Unit, Athens, Georgia; phone (706) 546-3356.*

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Upcoming in the December Issue

- Oatrim, an ARS-developed fat replacer, gets high marks in its first tryout with 24 human volunteers. LDL cholesterol dropped without decreasing beneficial HDL cholesterol.
- Genetic fingerprinting discloses the ancestry of unrelated plant look-alikes.
- Old and new "exotics" to treat the eye and tempt the palate—a colorful array of lettuce, hairy peanuts, and edible ornamental peppers.